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(54) Interpolation device for scale arrangement

Interpolationsgerät für Skalenanordnung

Appareil d'interpolation pour une échelle graduée

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(56) References cited:
EP-A- 0 377 045

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to improvements in an interpolation device for a scale arrangement, and more particularly to an interpolation device for a scale arrangement which arrangement is used for detecting a rotational position of a motor, movement of a table in a machine tool and the like.

2. Description of the Prior Art

Various types of a scale arrangement have been proposed and practically used in order to detect a position of a moving subject such as a rotational position of a motor or a movement of a table in a machine tool. A typical scale arrangement has a sensor such as a magnetic sensitive element which implements a readout of a scale in the form of an electrical signals of a sine wave and a cosine wave, and obtains the moving direction and position by analyzing the detected signals.

However, it is difficult to make a scale arrangement so as to keep a distance and an angle between a scale T and a sensor S constant during the operation of the scale arrangement. For example, the sensor S generates a waving relative to the scale T as shown in Fig. 5, and the inclined angle of the sensor S relative to the scale T becomes different in the forward movement and the backward movement as shown in Fig. 6. Furthermore, Abbe's error occurs when the sensor S is not aligned parallel with the scale T in a non-contact type scale arrangement as shown in Fig. 7. Accordingly, a signal detected by the sensor S includes various errors. For example, a DC offset voltage O_A, O_B is included in the signal as shown in Fig. 8; a deviation of a gain level is generated as shown in Fig. 9; a gain of the sine wave signal and a gain of the sine wave signal become different as shown in Fig. 10; and a phase drift between the sine wave signal and the cosine wave signal is generated. Although these errors are negligible in a scale arrangement which is not required to have a high discrimination, these errors can not be negligible when a scale arrangement is required to have a high discrimination such as 0.5µm, 0,1µm or 0.05 µm. Furthermore, such errors appears as a fatal error in a long-size scale arrangement requiring a high discrimination. Conventionally, the generation of such errors during movement of the sensor S has been prevented by the improvement of a mechanical structure. However, this mechanical improvement requires a fine machining degree in the structure, and therefore raises a production cost.

EP-A-0 377 045 discloses an encoder comprising first and second means for generating two sinusoidal scaling signals nominally 90° out of phase, first and second offset-correction means for the elimination of offset values in the first and second sinusoidal scaling signals, first and second amplitude correction means for the elimination of an amplitude difference in the first and second sinusoidal scaling signals, and first and second phase-correction means for adjusting the phase-difference between the first and second sinusoidal scaling signals to 90°.

In view of the prior art it is the object of the present invention to provide an interpolation device which may be constructed in a less expensive way, providing an inexpensive and high-productive scale arrangement with high accuracy.

This object is solved by the subject matter of claim 1.

Preferred embodiments of the present invention are the subject matter of the dependent claims 2 and 3.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, like reference numerals designate like elements and like parts throughout all figures, in which:

Fig. 1 is a block diagram which shows a first embodiment of an interpolation device for a scale arrangement;
Fig. 2 is a block diagram of a preferred example of a decision circuit applied to the interpolation device of Fig. 1;
Fig. 3 is a block diagram which shows a second embodiment of an interpolation device for the scale arrangement;
Fig. 4 is a block diagram which shows the interpolation device for the scale arrangement according to the present invention;
Fig. 5 is a view showing a reading characteristic of the scale arrangement;
Fig. 6 is a view showing an installing condition of sensors in the scale arrangement;
Fig. 7 is a view which shows another reading characteristic of the scale arrangement;
Fig. 8 is a graph showing an offset of a signal inputted in the interpolation device according to the present invention;
Fig. 9 is a graph showing a deviation of a gain level of the signal inputted in the interpolation device according to the present invention;
Fig. 10 is a graph which shows an unbalance of gain of the signal inputted in the interpolation device according

to the present invention;
Fig. 11 is a graph which shows a phase drift of the signal inputted in the interpolation device according to the present invention;
Fig. 12 is a graph which shows a relationship between the detected signal and a digital signal thereof; and
Fig. 13 is a graph which shows a relationship between an amplitude and angle of sine and cosine waves.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 1, there is shown a first embodiment of an interpolation device for a scale arrangement.

As shown in Fig. 1, sensors 1 and 2 in the interpolation device obtain inputs B and A, respectively which inputs are represented by the following equations (1) and (2):

$$A=K_A\sin(\theta+X)+O_A \tag{1}$$

$$B=K_B\cos\theta+O_B \tag{2}$$

where K_A is an amplitude coefficient of the input A; K_B is an amplitude coefficient of the input B; O_A is an offset value of the input A; O_B is an offset value of the input B; and X is a phase shift.

The input B is converted into a digital signal through an A/D converter within the sensor 1, and the converted signal is applied to one of two input terminals of the adder 3. The other input terminal of the adder 3 receives an average value (offset value) of an amplitude signal in a previous operation from an average circuit 5. As a result of the adding in the adder 3, a digital signal B1 from which an offset has been removed is outputted from the adder 3. Since the offset value is obtained as an average value between a maximum amplitude B_{max} and a minimum amplitude B_{min} as shown in Fig. 8, the average value O_B in the previous operation is represented by the following equation (3):

$$O_B = (B_{max} + B_{min})/2 \tag{3}$$

Since the digital signal B1 is obtained by subtracting the offset value O_B from the input B, the digital signal B1 is represented by the following equation (4):

$$B1 = B\text{-}O_B = K_B\cos\theta \tag{4}$$

The obtained digital signal B1 is applied to peak hold circuits 7 and 9, and a divider 13. The peak hold circuit 7 holds the maximum value Bmax of the input B according to a signal from a decision circuit 15. The peak hold circuit 9 holds a minimum value B_{min} of the input B according to the signal from the decision circuit 15. The outputs from the peak hold circuits 7 and 9 are applied to the averaging circuit 5. In the averaging circuit 5, an average value is calculated as shown in the equation (3). The obtained average value is changed in polarization and then kept on. The output from the averaging circuit 5 is applied to an adder 11 wherein the output from the averaging circuit 5 is added with the maximum value B_{max} from the peak hold circuit 7. The value K_B obtained by the adder 11 represents an amplitude coefficient of the signal B and is derived by the following equation (5):

$$K_B = B_{max} - (B_{max} + B_{min})/2$$

$$= (B_{max} - B_{min})/2 \tag{5}$$

The value B1 represented by the equation (4) and the value K_B represented by the equation (5) are inputted into the divider 13, and a value B2 is obtained by dividing the equation (4) by the equation (5) and therefore represented as a normalized cosine wave by the following equation (6):

$$B2 = \frac{B1}{K_B} = \frac{K_B\cos\theta}{K_B} = \cos\theta \tag{6}$$

Similarly, the input signal A is processed in the device shown in Fig. 1. That is, the input signal A is converted into a digital signal by an A/D converter of the sensor 2. Next, an offset value O_A is subtracted from the converted digital signal through an adder 4. Further, a value A1 is normalized by the divider 14. Such translations are represented by the following equations (7), (8), (9) and (10):

$$O_A = (A_{max} + A_{min})/2 \quad (7)$$

$$A1 = A - O_A = K_A \sin(\theta + X) \quad (8)$$

$$K_A = A_{max} - (A_{max} + A_{min})/2$$

$$= (A_{max} - A_{min})/2 \quad (9)$$

$$A2 = \frac{A1}{K_A} = \sin(\theta + X) \quad (10)$$

An latch circuit 17 latches data $\sin(\theta + X)$ by every input of the maximum value B_{max} into the peak hold circuit 7. Since the signal B takes a maximum value when $\theta = 2n\pi$ (n is positive integer), the latch circuit 17 latches a value A3 represented by the following equation (11):

$$A3 = \sin(\theta + X) = \sin(2n\pi + X) = \sin X \quad (11)$$

An inverse function $X = \sin^{-1}A3$ of the equation (10) is obtained by an inverse function generator 20. The obtained inverse function X is applied to adders 19 and 21. On the other hand, an inverse function generator 16 outputs a value $\theta = \cos^{-1}B2$. Then, the value $\theta = \cos^{-1}B2$ is added to the value X in the adder 19. More particularly, when θ takes a value positioned in the first or third quadrant, the output value from the adder 19 becomes $\theta + X$. When in the second or fourth quadrant, the output value from the adder 19 becomes $\theta - X$. A function generator 22 generates a cosine wave signal $\cos(\theta \pm X)$ according to the output $\theta \pm X$ from the adder 19.

An inverse function generator 18 generates a value $\theta + X = \sin^{-1}A2$ and applies to an adder 21. In the adder 21 the value $\theta + X = \sin^{-1}A2$ from the inverse function generator 18 is added to the signal X from the inverse function generator 20. More particularly, when θ takes a value positioned in the first or third quadrant, the output value from the adder 21 becomes $(\theta + X) - X$. When in the second or fourth quadrant, the output value from the adder 21 becomes $(\theta + X) + X$. The polarity of the value X is determined according to the plus or minus character of $\cos(\theta + X)$.

The adder 21 outputs $\theta = \theta + X - X$, and the function generator 23 generates a correct sine wave signal $\sin\theta$ by removing the phase drift from the input signal. The inverse function generator 24 calculates $\tan\theta$ according to $\sin\theta$ from the function generator 23 and $\cos\theta$ from the divider 13, and outputs θ which is an inverse function of $\tan\theta$. With this operations in the interpolation device, a correct measured output θ is obtained upon removing the phase drift during a detection by the sensor.

The manner of operation of the decision arrangement 15 will be discussed hereinafter in detail with reference to Fig. 2.

Since a scale readout on the scale S is obtained as a periodical function, the explanation of this embodiment is proceeded upon assuming that one period λ of the periodical function is 200 ($\lambda = 200$). As shown in Fig. 12, one period of the periodical function is corresponding digital signals 0 to 199. Accordingly, when the sensor is moved in the forward direction (rightward in Fig. 12), the digital signal suddenly decreased from 199 to 0. When the sensor is moved in the backward direction (leftward in Fig. 12), the digital signal suddenly increases from 0 to 199. Accordingly, it is necessary to detect the moving direction of the sensor first. The latch circuit 67 keeps a previously measured signal and outputs it to the compactors 69 and 70. The previously measured signal is compared with predetermined values 20 and 180 in the comparators 69 and 70, respectively. The comparator 69 outputs a logical output 1 (high level) when the previous digital signal is larger than 180. The comparator 68 outputs a logical output 1 (low level) when the now digital signal is smaller than 20. Both outputs applies a logical input 1 to one of two input terminals of an AND circuit 81 through an AND circuit 75 and an OR circuit 83. This input is applied to a clock CK of a latch circuit 79, and the latch circuit 79 latches a new digital signal. At this time, a D flip-flop 77 is set according to the output of the comparator 69 such that

the data in the forward direction is valid.

Similarly, The comparator 70 outputs an output 1 when the previous digital signal is smaller than 20. When the now digital signal is larger than 180, the comparator 71 outputs a logical output 1. Both outputs applies a logical input 1 to one of two input terminals of an AND circuit 82 through an AND circuit 73 and an OR circuit 84. This input is applied to a clock CK of a latch circuit 80 such that the latch circuit 80 latches a now digital signal. At this time, a D flip-flop 78 is set according to the output of the comparator 70 such that the data in the backward direction is valid. Since the output of a comparator 89 is 0 in both above-mentioned case, a clock input of a D flip-flop circuit is set at 0 (low level).

For example, when the sensor is moving in the forward direction, an input A of the comparator 89 is increasing and at last a condition $A \geqq B$ is satisfied. In this situation, the clock input of the D flip-flop circuit 91 becomes 1 (high level), and the D flip-flop circuit 91 is set. Next, a D flip-flop circuit 92 is set, and a D flip-flop circuit 93 is set according to the output of the D flip-flop circuit 92. Accordingly, the D flip-flop circuit 93 outputs a decision output indicative that the sensor has moved one period (has passed a portion between digital signals 199 and 0). When the D flip-flop circuit 92 is turned on, the D flip-flop 77 is turned on. When the D flip-flop 92 is turned off by a next clock input, the D flip-flop 78 is turned on. Accordingly, the data in the both direction is treated to be valid, and the operation is repeated to a next period.

With this arrangement of the interpolation device, since errors generated by the mechanical play during the moving operation of the sensor is electrically interpolated, the mechanical structure of the scale arrangement is formed simple.

Fig. 3 shows a second embodiment of the interpolation device of the scale arrangement. In the drawing, same numerals designate same parts and elements as that in Fig. 1, and the explanation thereof are facilitated herein.

A divider 25 receives an output K_B of an adder 11 and an output K_A of an adder 12 and outputs an output K_B/K_A. A multiplier 26 receives a signal represented by the equation (8) from the adder 4 and a signal K_B/K_A from the divider 25 and outputs an output A2 which is represented by the following equation (12):

$$A2 = \frac{K_B}{K_A} K_A \sin(\theta + X) = K_B \sin(\theta + X) \tag{12}$$

By this calculation, an amplitude of a sine wave signal becomes the same as that of a cosine wave signal. By adding the output of the adder 3 to the output of the multiplier 26 at an adder 28, a signal A3 represented by the following equation (13) is obtained.

$$A3 = K_B \{\sin(\theta + X) - \cos\theta\} \tag{13}$$

The equation (13) is modified as represented by the following equation (14):

$$\begin{aligned} A3 &= -K_B \{\sin(\theta + X) - \cos\theta\} \\ &= -K_B \{\sin(\theta + X) + \sin(\theta + \frac{\pi}{2})\} \\ &= 2K_B \{\sin(\frac{\pi}{4} - \frac{X}{2})\cos(\theta + \frac{X}{2} + \frac{\pi}{4}) \end{aligned} \tag{14}$$

$$K'_A = 2K_B \sin(\frac{\pi}{4} - \frac{X}{2}) \tag{15}$$

Since K_A' in the equation (15) indicates an amplitude, the peak hold circuit 30 holds the value represented by the equation (15).

Similarly, by adding the output of the adder 3 to the output of the multiplier 26 at an adder 27, a signal B3 represented by the following equation (13) is obtained.

$$B3 = K_B \{\sin(\theta + X) + \cos\theta\} \tag{16}$$

The equation (16) is modified as represented by the following equation (17):

$$B3 = K_B \{\sin(\theta + X) + \cos\theta\}$$

$$= K_B \{\sin(\theta + X) + \sin(\theta + \frac{X}{2})\}$$

$$= 2K_B \sin(\theta+\frac{X}{2}+\frac{\pi}{4})\cos(\frac{\pi}{4}-\frac{X}{2}) \quad (17)$$

$$K'_B = 2K_B\cos(\frac{\pi}{4}-\frac{X}{2}) \quad (18)$$

Since K_B' in the equation (18) indicates an amplitude, the peak hold circuit 29 holds the value represented by the equation (18). By dividing the value held in the peak hold circuit 30 by the value held in the peak hold circuit 29 at the divider 31, a value represented by the following equation (19) is obtained.

$$\frac{K'_A}{K'_B} = \frac{2K_B\sin(\frac{\pi}{4}-\frac{X}{2})}{2K_B\cos(\frac{\pi}{4}-\frac{X}{2})} = \tan(\frac{\pi}{4}-\frac{X}{2}) \quad (19)$$

The obtained value outputted from the divider 31 is modified by an inverse function generator 33 as shown by the following equation (20):

$$\tan^{-1}\frac{K'_A}{K'_B} = \frac{\pi}{4}-\frac{X}{2} \quad (20)$$

The equation (15) is modified into the following equation (21):

$$K'_A = 2K_B\sin(\frac{\pi}{4}-\frac{X}{2})$$

$$= 2K_B\cos(\frac{\pi}{2}-\frac{\pi}{4}+\frac{X}{2})$$

$$=2K_B\cos(\frac{\pi}{4}+\frac{X}{2}) \quad (21)$$

Similarly, the equation (18) is modified into the following equation (22):

$$K'_B = 2K_B\cos(\frac{\pi}{4}-\frac{X}{2})$$

$$= 2K_B\sin(\frac{\pi}{2}-\frac{\pi}{4}+\frac{X}{2})$$

$$=2K_B\sin(\frac{\pi}{4}+\frac{X}{2}) \quad (22)$$

Accordingly, by dividing the output of the peak hold circuit 29 by the output of the peak hold circuit 30, a value represented by the following equation (23) is obtained.

$$\frac{K'_B}{K'_A} = \frac{2K_B\sin(\frac{\pi}{4}+\frac{X}{2})}{2K_B\cos(\frac{\pi}{4}+\frac{X}{2})} = \tan(\frac{\pi}{4}+\frac{X}{2}) \quad (23)$$

Since the output of the adder 28 has been applied by the equation (14), the equation (14) is rewritten by using the equation (21) as follows:

$$A3 = 2K_B\cos(\frac{\pi}{4}+\frac{X}{2})\cos(\theta + \frac{X}{2} + \frac{\pi}{4}) \quad (24)$$

Therefore, by multiplying the output of the adder 28 represented by the equation (24) and the output of the divider 32 represented by the equation (23) at the multiplier 35, a value represented by the following equation (25) is obtained:

$$A4 = \frac{\sin(\frac{\pi}{4}+\frac{X}{2})}{\cos(\frac{\pi}{4}+\frac{X}{2})} \cdot 2K_B \cos(\frac{\pi}{4}+\frac{X}{2}) \cos(\theta + \frac{X}{2} + \frac{\pi}{4})$$

$$= 2K_B \sin(\frac{\pi}{4}+\frac{X}{2}) \cos(\theta + \frac{\pi}{4} + \frac{X}{2}) \quad (25)$$

By deforming the equation (17) as implemented in the equation (22), the output of the adder 27 is represented by the following equation (26):

$$B4 = 2K_B \sin(\frac{\pi}{4}+\frac{X}{2}) \sin(\theta + \frac{\pi}{4} + \frac{X}{2}) \quad (26)$$

Since the amplitude of the equation (26) is the same as that of the equation (25), the following equation (27) is obtained by the division of the equation (26) by the equation (25).

$$\frac{B4}{A4} = \tan(\theta + \frac{\pi}{4} + \frac{X}{2}) \quad (27)$$

An inverse function generator 24 calculates an inverse function of the equation (27) and outputs a valued represented by the following equation (28):

$$\tan^{-1} \frac{B4}{A4} = \theta + \frac{\pi}{4} + \frac{X}{2} \quad (28)$$

An inverse function generator 33 calculated an inverse function of the equation (19) and outputs a value represented by the following equation (29):

$$\tan^{-1} \frac{K'_A}{K'_B} = \frac{\pi}{4} - \frac{X}{2} \quad (29)$$

Accordingly, the adder 36 calculates the sum of the output of the inverse function generator 24 represented by the equation (28) and the output of the inverse function generator 33 represented by the equation (29) and outputs a signal as follows:

$$(\theta + \frac{\pi}{4} + \frac{X}{2}) + (\frac{\pi}{4} - \frac{X}{2}) = \theta + \frac{\pi}{2}$$

The signal is a correct without phase lag X and used as a measured output. The signal is applied to a decision box 15 as mentioned above and used for generating a synchronizing signal. Accordingly, errors generated by the mechanical lag during the moving operation of the sensor is interpolated electrically, it is possible that the mechanical structure of the scale arrangement is formed simple.

Referring to Fig. 4, there is shown the interpolation device of the scale arrangement according to the present invention. In the drawing, same numerals designate same parts and elements as that in Fig. 3, and the explanation thereof are facilitated herein.

A divider 32 output a signal represented by the equation (23) $\tan(\frac{\pi}{4}+\frac{X}{2})$. An inverse function generator 37 outputs an inverse function of the equation (23) as follows:

$$\tan^{-1} \frac{K'_B}{K'_A} = \frac{\pi}{4} + \frac{X}{2} \quad (30)$$

In an adder 34, $-\frac{\pi}{4}$ is added to the value represented by the equation (30). Then, the multiplier 38 outputs X which is

twice the output of the adder 34. Function generators 39 and 40 generate signals sinX and cosX, respectively, by using the output of the multiplier 38. The plus-minus signal inversion of the signal sinX is transformed in the sign inversion circuit 41. Then, the plus-minus signal inverted value is added to 1 in an adder 43, and a signal represented by the following equation (31) is ouputted from the adder 43.

$$C = 1 - \sin X \tag{31}$$

In a multiplier 44, the output of the adder 3 represented by the equation (4) and the signal represented by the equation (31) are multiplied, and a signal represented by the following equation (32) is outputted:

$$B5 = K_B \cos\theta \cdot (1 - \sin X) \tag{32}$$

The signal B5 represented by the equation (32) is added to the signal obtained by implementing the signal inversion 49 of the output of the adder 3 in an adder 45, and a signal represented by the following equation (33) is outputted:

$$\begin{aligned} B6 &= K_B \cos\theta \cdot (1 - \sin X) - K_B \cos\theta \\ &= - K_B \cos\theta \sin X \end{aligned} \tag{33}$$

The signal B6 is added to the output of the multiplier 26 represented by the equation (12) in an adder 46, and a signal represented by the following equation (34) is outputted from the adder 46.

$$\begin{aligned} B7 &= K_B \cos\theta \sin X + K_B \sin(\theta + X) \\ &= K_B \sin\theta \cos X \end{aligned} \tag{34}$$

Next, the signal represented by the equation (34) is multiplied with an inverse number of cosX from the divider 42 in a multiplier 47, and a signal represented by the following equation (35) is outputted.

$$B8 = K_B \sin\theta \cos X \cdot \frac{1}{\cos X} = K_B \sin\theta \tag{35}$$

On the basis of the signal represented by the equation (35) and the output of the adder 3, an inverse function generator 24 generates a signal represented by the following equation (36) and then outputs a signal represented by the following equation (37):

$$\frac{B8}{B1} = \frac{K_B \sin\theta}{K_B \cos\theta} = \tan\theta \tag{36}$$

$$\tan^{-1} \frac{B8}{B1} = \theta \tag{37}$$

The obtained signal θ is a correct value without a phase drift and applied as a result of a measured signal. With this arrangement of the interpolation device according to the present invention, since errors generated by the mechanical lag during the moving operation of the sensor is interpolated by electrically, it is possible that the mechanical structure of the scale arrangement is formed simple.

Claims

1. An interpolation device for a scale arrangement, comprising:

a first input means (2) receiving an input sine wave signal from the scale arrangement;

a second input means (1) receiving an input cosine wave signal from the scale arrangement;

a first output means comprising a first offset value calculating circuit (4,6,8,10) which calculates an offset value of the input sine wave signal and a first amplitude coefficient calculating circuit (6,8,10,12) which calculates an amplitude coefficient of the input sine wave signal, said first output means outputting an interpolated sine wave signal from which the offset value of the input sine wave has been removed and which has a first predetermined amplitude coefficient according to the values from the first offset value calculating circuit and the first amplitude coefficient calculating circuit;

a second output means comprising a second offset value calculating circuit (3,5,7,9) which calculates an offset value of the input cosine wave signal and a second amplitude coefficient calculating circuit (5,7,9,11) which calculates an amplitude coefficient of the input cosine wave signal, said second output means outputting a cosine wave signal from which the offset value of the input cosine wave is removed and which has a second predetermined amplitude coefficient according to the values from the second offset value calculating circuit and the second amplitude coefficient calculating circuit;

a correcting means (42,46,47) correcting a phase drift between the sine wave signal from said first output means and the cosine wave signal from said second ouput means, said correcting means outputting a correct measured angle on the basis of the corrected sine and cosine wave signals in phase drift; and

a decision means (15) for deciding an accomplishment of one period of measuring period on the basis of the correct measured angle signal of said correcting means and outputting a synchronizing signal to said first output means, said second output means and said correcting means,

characterised in that
said correcting means generates a signal indicative of the product (K_B.sinθ cosX) of a drift signal indicative of a phase drift condition between the sine wave signal from the first output means and the cosine wave signal from the second output means and an angular signal (K_B.sinθ) indicative of a measuring angle signal on the basis of the sine wave signal and the cosine wave signal, said correcting means calculating the drift signal indicative of the phase drift condition independently and obtaining the correct measured angle signal by dividing (42,47) the product signal by the independently obtained drift signal (cosX).

2. An interpolation device as in claim 1,
wherein the offset value calculating circuit comprises a maximum value latch circuit (7,8) for latching a maximum value of amplitude of the input signal and a minimum value latch circuit (9,10) for latching a minimm value of amplitude of the input signal, the offset value calculating circuit calculating the offset value by averaging the maximum value latched in the maximum value latch circuit and the minimum valve latched in the minimum value latch circuit.

3. An interpolation device as in any of the claims 1-2,
wherein the amplitude coefficient calculating circuit comprises a circuit (6,8,10,12;5,7,9,11) for calculating amplitude of the input signal as a half of a distance between a maximum value and a minimum value of the amplitude of the input signal.

Patentansprüche

1. Interpolationseinrichtung für eine Skalierungsvorrichtung, mit:

einer ersten Eingabeeinrichtung (2) zum Empfangen eines Eingangssinussignals von der Skalierungsvorrichtung;

einer zweiten Eingangseinrichtung (1) zum Empfangen eines Eingangskosinussignals von der Skalierungsvorrichtung;

einer ersten Ausgabeeinrichtung mit einem ersten Offsetwert-Berechnungsschaltkreis (4, 6,8,10), der einen

Offsetwert des Eingangssinussignals berechnet, und einem ersten Amplitudenkoeffizienten-Berechnungsschaltkreis (6,8, 10, 12), der einen Amplitudenkoeffizienten des Eingangssinussignals berechnet, wobei die erste Ausgangseinrichtung ein interpoliertes Sinussignal ausgibt, von dem der Offsetwert des Eingangssinussignals entfernt wurde und das einen ersten vorbestimmten Amplitudenkoeffizienten entsprechend den Werten von dem ersten Offsetwert-Berechnungsschaltkreis und dem ersten Amplitudenkoeffizienten-Berechnungsschaltkreis aufweist;

einer zweiten Ausgabeeinrichtung mit einem zweiten Offsetwert-Berechnungsschaltkreis (3,5,7,9), der einen Offsetwert des Eingangskosinussignals berechnet und einem zweiten Amplitudenkoeffizienten-Berechnungsschaltkreis (5,7,9,11), der einen Amplitudenkoeffizienten des Eingangskosinussignals berechnet, wobei die zweite Ausgabeeinrichtung ein Kosinussignal ausgibt, bei dem der Offsetwert des Eingangskosinussignals entfernt wurde und das einen zweiten vorbestimmten Amplitudenkoeffizienten entsprechend den Werten von dem zweiten Offset-Berechnungsschaltkreis und dem zweiten Amplitudenkoeffizienten-Berechnungsschaltkreis aufweist;

einer Korrektureinrichtung (42, 46, 47) zum Korrigieren einer Phasendrift zwischen dem Sinussignal und der ersten Ausgabeeinrichtung und dem Kosinussignal von der zweiten Ausgabeeinrichtung, wobei die Korrektureinrichtung einen korrekten Meßwinkel auf Grundlage eines hinsichtlich der Phasendrift korrigierten Sinus- und Kosinussignals ausgibt; und

einer Entscheidungseinrichtung (15) zum Entscheiden einer Erreichung einer Periode von der Meßperiode auf Grundlage des korrigierten Meßwinkelsignals der Korrektureinrichtung und zum Ausgeben eines Sychronisationssignals an die erste Ausgabeeinrichtung, die zweite Ausgabeeinrichtung und die Korrektureinrichtung,

dadurch gekennzeichnet, daß
die Korrektureinrichtung ein Signal erzeugt, das das Produkt (K_B. Sinθ cosX) eines Driftsignals angibt, welches die Phasendriftbedingung zwischen dem Sinussignal von der ersten Ausgabeeinrichtung und dem Kosinussignal von der zweiten Ausgabeeinrichtung angibt und ein Winkelsignal (K_B. Sinθ) angibt, das ein Meßwinkelsignal auf Grundlage des Sinussignals und des Kosinussignals angibt, wobei die Korrektureinrichtung das Driftsignal, welches die Phasendriftbedingung angibt, unabhängig berechnet und das korrigierte Meßwinkelsignal durch Dividieren (42,47) des Produktsignals durch das unabhängig erhaltene Driftsignal (cosX) erhält.

2. Interpolationseinrichtung nach Anspruch 1, wobei der Offsetwert-Berechnungsschaltkreis einen Maximumwert-Latch-Schaltkreis (7,8) zum Zwischenspeichern eines Maximalwertes einer Amplitude des Eingangssignals und einen Minimumwert-Latch-Schaltkreis (9, 10) zum Zwischenspeichern eines Minimalwertes der Amplitude des Eingangssignals aufweist, wobei der Offsetwert-Berechnungsschaltkreis den Offsetwert durch Mitteln des Maximumwertes, der in dem Maximalwert-Latch-Schaltkreis gespeichert ist und des Minimumwertes, der in dem Minimumwert-Latch-Schaltkreis gespeichert ist, berechnet.

3. Interpolationseinrichtung nach einem der Ansprüche 1 bis 2,
wobei der Amplitudenkoeffizienten-Berechnungsschaltkreis einen Schaltkreis (6, 8, 10, 12; 5, 7, 9, 11) zum Berechnen der Amplitude des Eingangssignals als die halbe Distanz zwischen Maximalwert und Minimalwert der Amplitude des Eingangssignals aufweist.

Revendications

1. Appareil d'interpolation pour une échelle graduée, comprenant:

des premiers moyens d'entrée (2) recevant de l'échelle graduée un signal d'entrée sous forme d'une onde sinusoïdale;
des seconds moyens d'entrée (1) recevant de l'échelle graduée un signal d'entrée sous forme d'une onde cosinusoïdale;
des premiers moyens de sortie comprenant un premier circuit de calcul de valeurs offset (4,6,8,10) calculant une valeur offset du signal d'entrée sinusoïdal et un premier circuit de calcul de coefficients d'amplitude (6,8,10,12) calculant un coefficient d'amplitude du signal d'entrée sinusoïdal, ces premiers moyens de sortie fournissant un signal sinusoïdal interpolé duquel la valeur offset de l'onde sinusoïdale d'entrée a été éliminée

et qui présente un premier coefficient d'amplitude prédéterminé découlant des valeurs fournies par ledit premier circuit de calcul de valeurs offset et par ledit premier circuit de calcul de coefficients d'amplitude;
des seconds moyens de sortie comprenant un second circuit de calcul de valeurs offset (3, 5, 7, 9) calculant une valeur offset du signal d'entrée cosinusoïdal et un second circuit de calcul de coefficients d'amplitude (5,7,9,11) calculant un coefficient d'amplitude du signal d'entrée cosinusoïdal, ces seconds moyens de sortie fournissant un signal cosinusoïdal duquel la valeur offset de l'onde cosinusoïdale a été éliminée et qui présente un second coefficient d'amplitude prédéterminé découlant des valeurs fournies par ledit second circuit de calcul de valeurs offset et par ledit second circuit de calcul de coefficients d'amplitude;
des moyens de correction (42, 46, 47) corrigeant un décalage de phases entre ledit signal sinusoïdal fourni par lesdits premiers moyens de sortie et ledit signal cosinusoïdal fourni par lesdits seconds moyens de sortie, ces moyens de correction fournissant an angle mesuré correctement sur la base des signaux sinusoïdal et cosinusoïdal en décalage de phase corrigés; et par des moyens de décision (15) pour décider de l'accomplissement d'une période de la période de mesure sur la base du signal d'angle mesuré correct fourni par les moyens de correction et fournissant un signal de synchronisation auxdits premier et second moyens de sortie et aux moyens de correction,

caractérisé en ce que lesdits moyens de correction fournissent un signal représentant le produit (K_B. SinΘ cosX) d'un signal de décalage représentant un état de décalage de phase entre le signal sinusoïdal provenant des premiers moyens de sortie et le signal cosinusoïdal provenant des seconds moyens de sortie, ainsi qu'un signal angulaire (K_B. SinΘ) représentant un signal de mesure d'angle sur la base desdits signaux sinusoïdal et cosinusoïdal, les moyens de correction calculant de manière indépendante le signal de décalage représentant l'état de la phase de décalage et obtenant le signal d'angle mesuré correct en divisant (42, 47) ledit signal représentant le produit par le signal de décalage (cosX) obtenu de manière indépendante.

2. Appareil d'interpolation selon la revendication 1, caractérisé en ce que le circuit pour calculer la valeur offset comprend un circuit d'arrêt de valeurs maximum (7,8) pour maintenir une valeur maximum de l'amplitude du signal d'entrée et un circuit d'arrêt de valeurs minimum (9,10) pour maintenir une valeur minimum de l'amplitude du signal d'entrée, ledit circuit de calcul de valeurs offset calculant la valeur offset en formant une valeur moyenne entre la valeur maximum maintenue dans ledit circuit d'arrêt de valeurs maximum et la valeur minimum maintenue dans ledit circuit d'arrêt de valeurs minimum.

3. Appareil d'interpolation selon l'une des revendications 1 ou 2, caractérisé en ce que le circuit de calcul du coefficient d'amplitude comprend un circuit (6,8,10,12; 5,7,9, 11) pour calculer l'amplitude du signal d'entrée comme la moitié d'une distance entre une valeur maximum et une valeur minimum de l'amplitude du signal d'entrée.

FIG.1

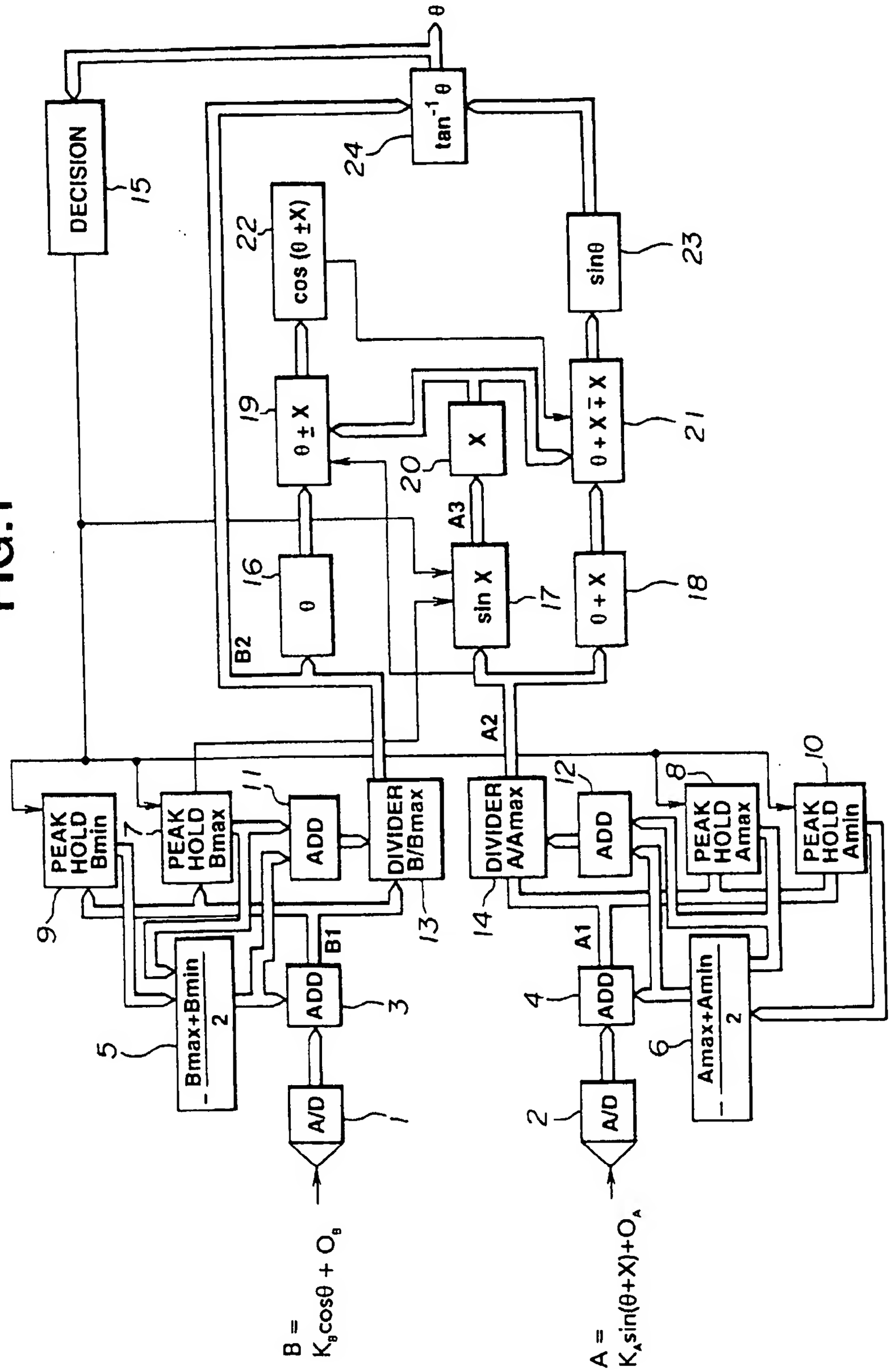
θ
DECISION
15
tan⁻¹ θ
24
cos (θ ±X)
22
sinθ
23
θ ± X
19
X
20
θ + X ± X
21
θ
16
B2
sin X
17
A3
θ + X
18
A2
PEAK HOLD Bmin
9
PEAK HOLD Bmax
7
ADD
11
DIVIDER B/Bmax
13
DIVIDER A/Amax
14
ADD
12
PEAK HOLD Amax
8
PEAK HOLD Amin
10
Bmax+Bmin
2
5
ADD
3
B1
A1
ADD
4
Amax+Amin
2
6
A/D
1
A/D
2
B = K_B cosθ + O_B
A = K_A sin(θ+X)+O_A

FIG.2

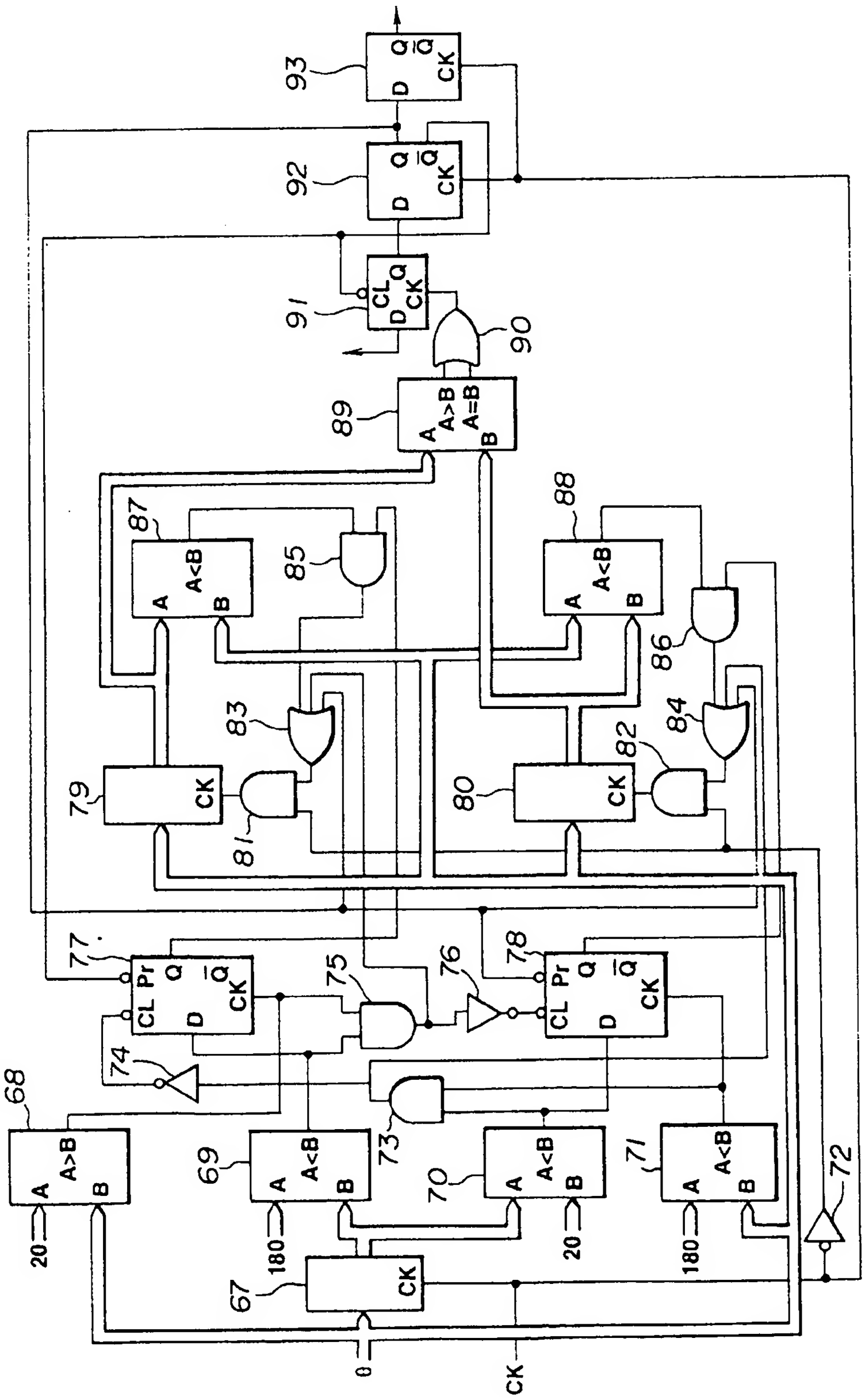
93
92
91
90
89
88
87
86
85
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
69
68
67
D
Q
CK
CL
Pr
A
B
A>B
A=B
A<B
20
180
0
CK

FIG.3

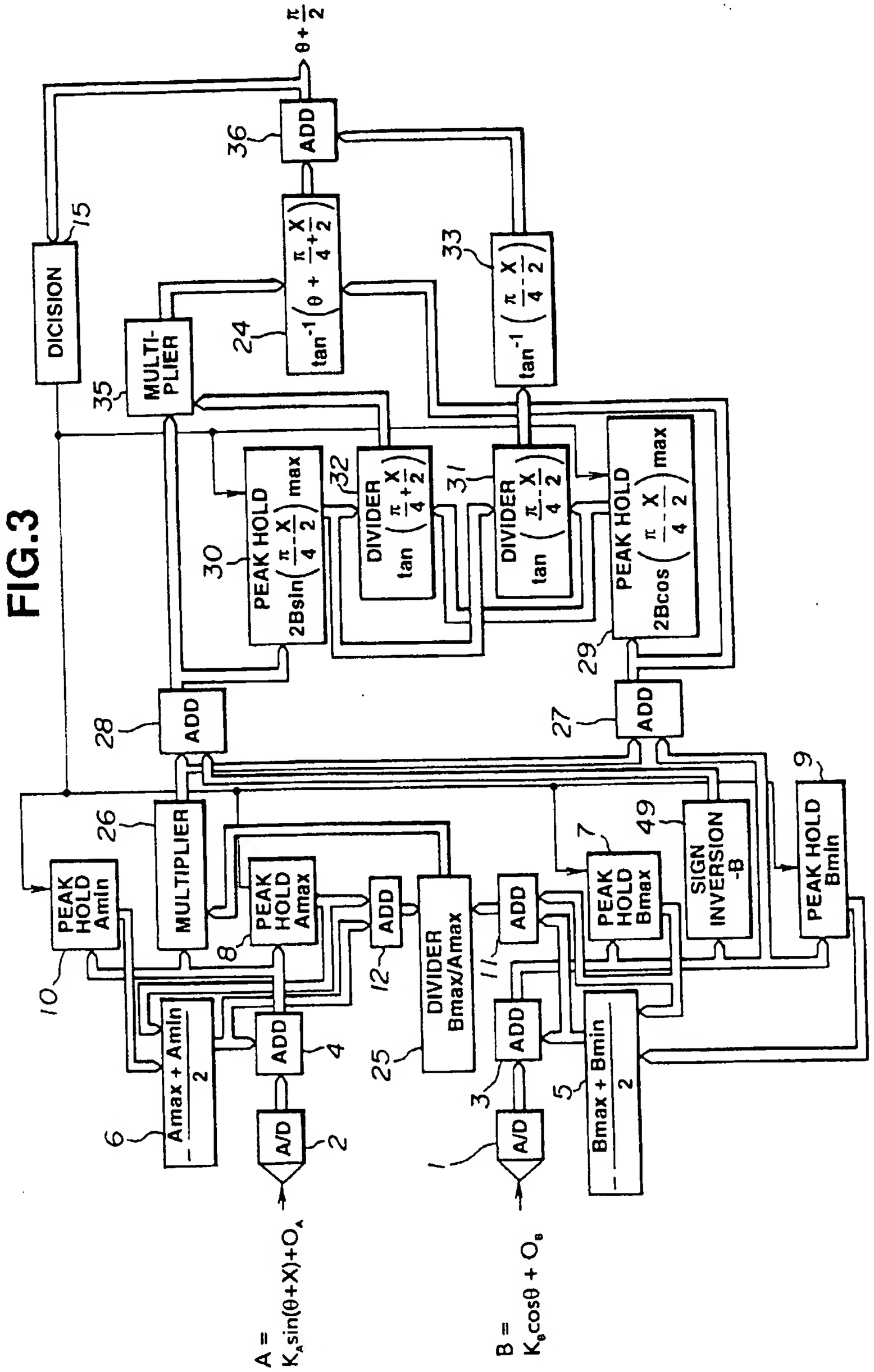
θ+π/2
36
ADD
15
DICISION
33
tan⁻¹(π/4 − X/2)
24
tan⁻¹(θ + π/4 + X/2)
35
MULTI-PLIER
30
PEAK HOLD 2Bsin(π/4 − X/2) max
32
DIVIDER tan(π/4 + X/2)
31
DIVIDER tan(π/4 − X/2)
PEAK HOLD 2Bcos(π/4 − X/2) max
29
28
ADD
27
ADD
26
MULTIPLIER
9
PEAK HOLD Bmin
49
SIGN INVERSION -B
7
PEAK HOLD Bmax
PEAK HOLD Amin
10
PEAK HOLD Amax
8
ADD
12
DIVIDER Bmax/Amax
11
ADD
ADD
4
ADD
25
6
Amax + Amin / 2
A/D
2
A = K_A sin(θ+X)+O_A
3
ADD
1
A/D
5
Bmax + Bmin / 2
B = K_B cosθ + O_B

FIG.4

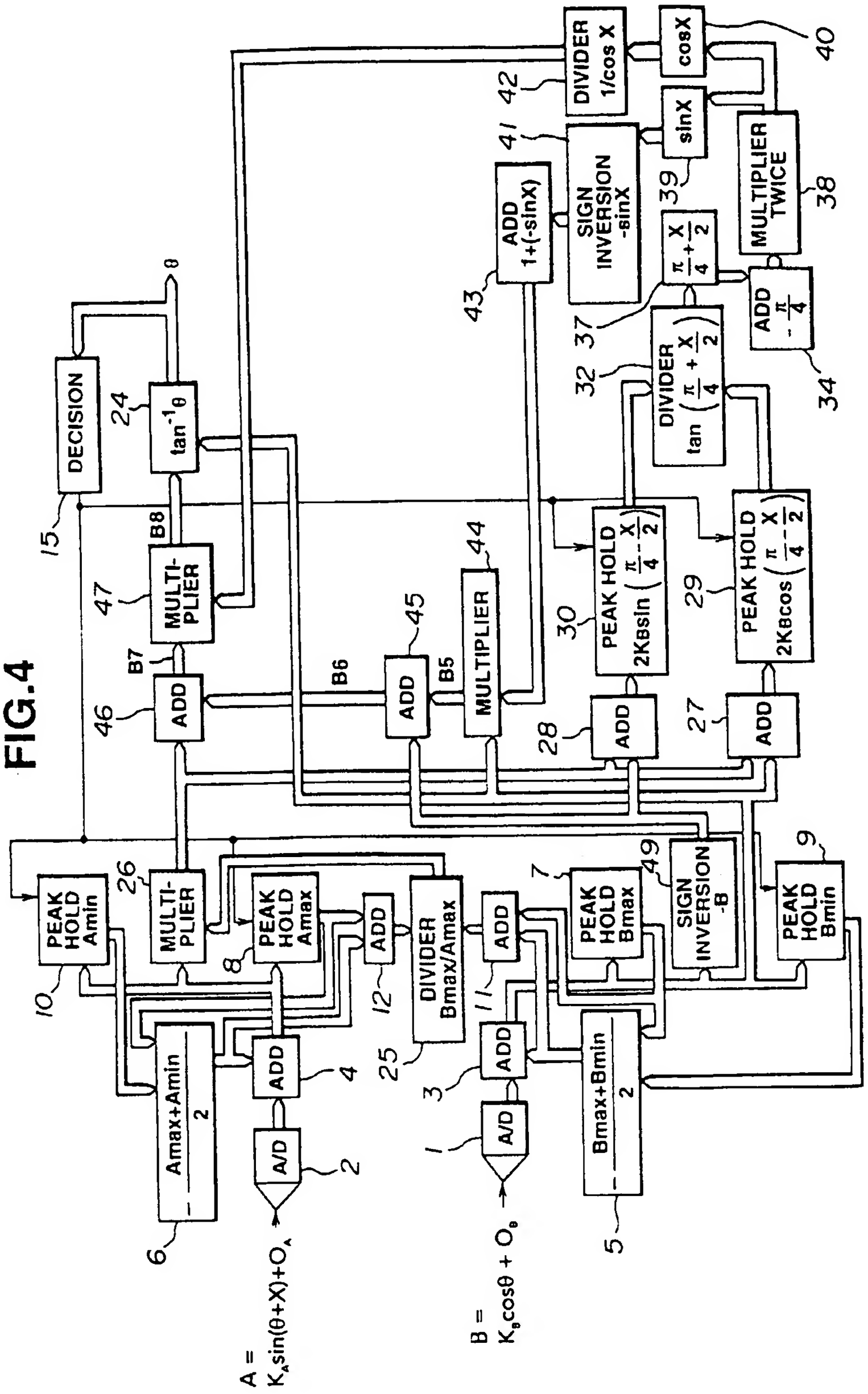
θ
DECISION
15
tan⁻¹θ
24
B8
MULTI-PLIER
47
B7
ADD
46
B6
ADD
45
B5
MULTIPLIER
44
DIVIDER 1/cos X
42
cosX
40
41
ADD 1+(-sinX)
43
SIGN INVERSION -sinX
sinX
39
MULTIPLIER TWICE
38
π/4 + X/2
37
DIVIDER tan(π/4 + X/2)
32
ADD -π/4
34
PEAK HOLD 2KBsin(π/4 - X/2)
30
PEAK HOLD 2KBcos(π/4 - X/2)
29
ADD
28
ADD
27
PEAK HOLD Amin
10
MULTI-PLIER
26
PEAK HOLD Amax
8
ADD
12
DIVIDER Bmax/Amax
25
ADD
11
PEAK HOLD Bmax
7
SIGN INVERSION -B
49
PEAK HOLD Bmin
9
Amax+Amin / 2
6
ADD
4
A/D
2
A = K_A sin(θ+X)+O_A
ADD
3
A/D
1
B = K_B cosθ + O_B
Bmax+Bmin / 2
5

FIG.5

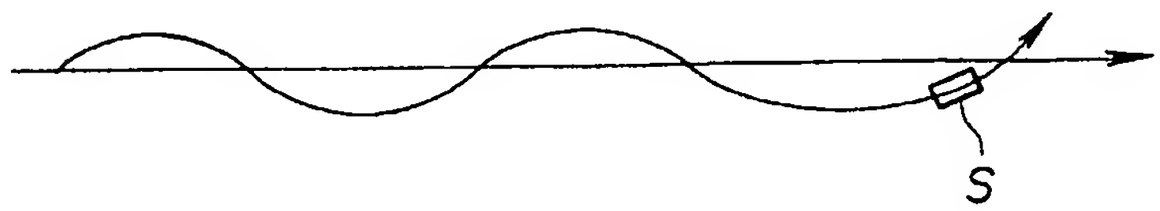

FIG.6

FIG.7

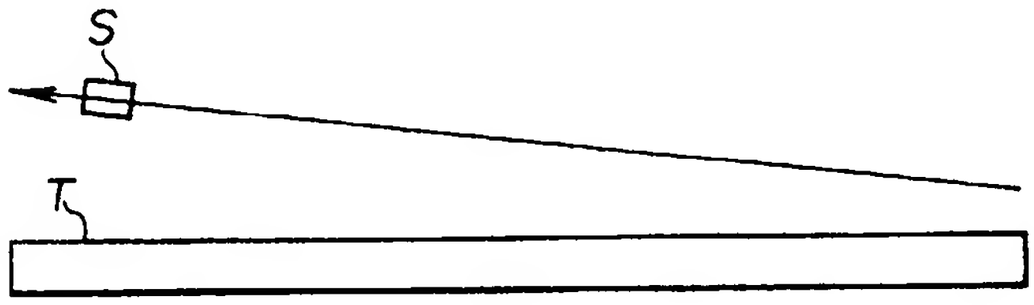

FIG.8

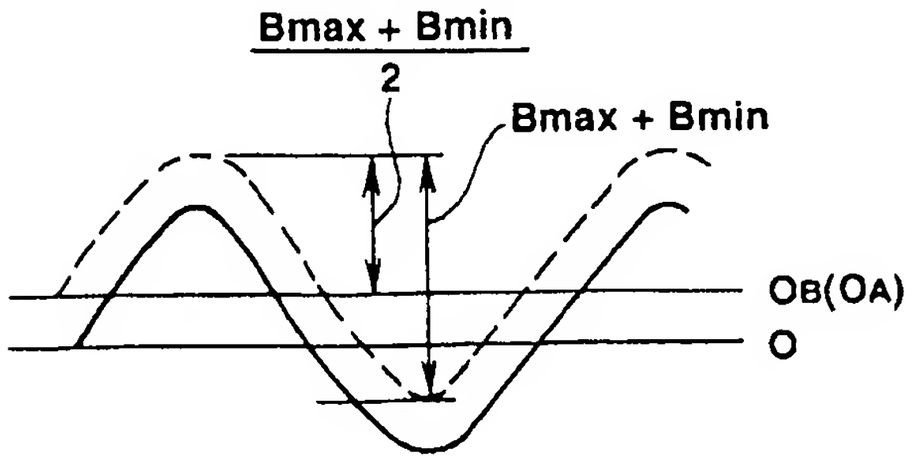

FIG.9

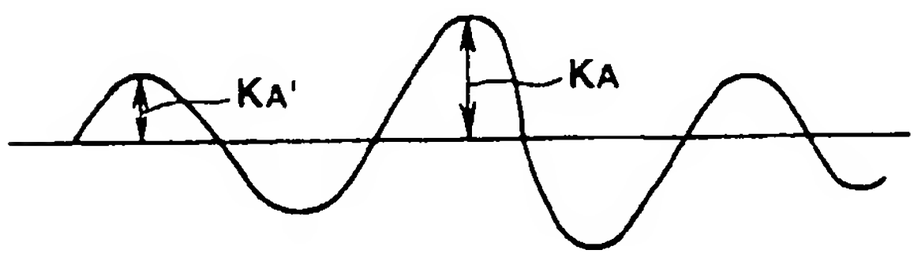

FIG.10

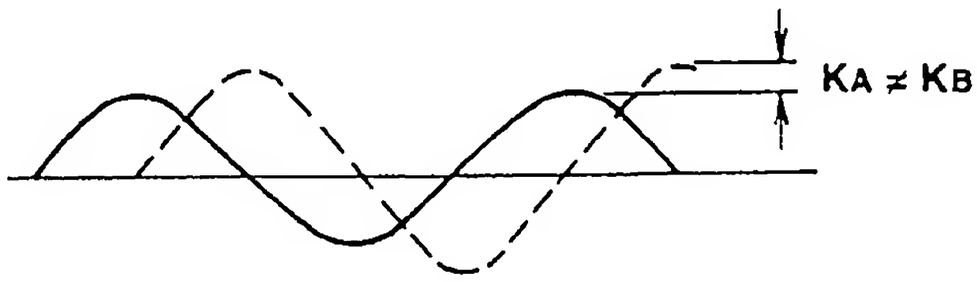

FIG.11

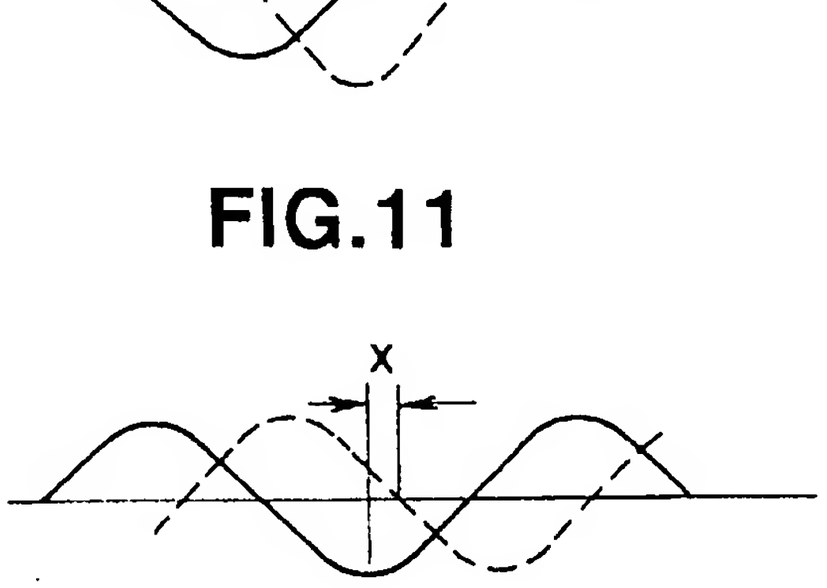

FIG.12

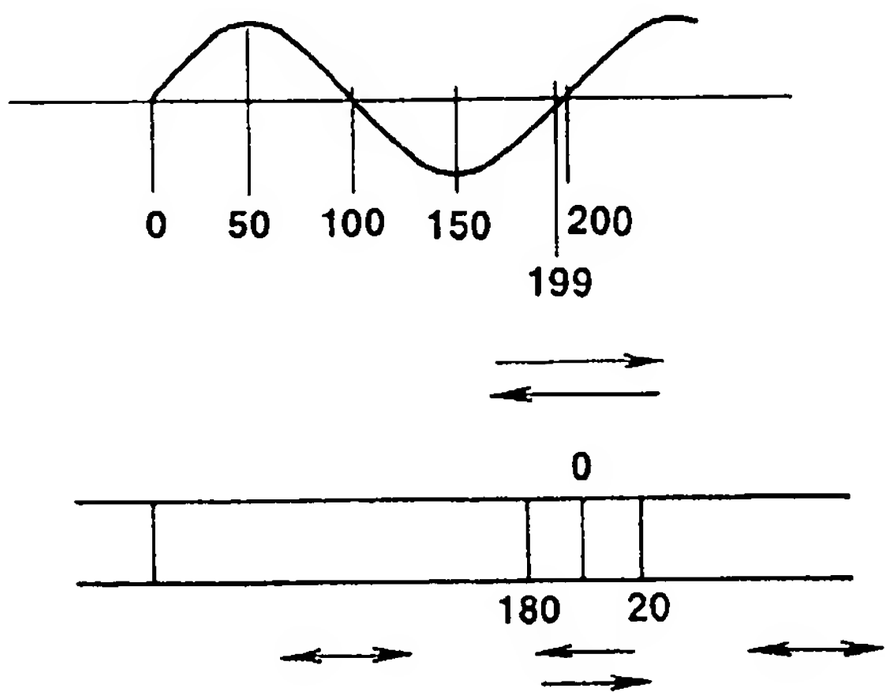

FIG.13